Thoughts on Design of an Outdoor Sports Sound System

By Tom Stuckman

This paper explores many of the considerations for designing a sound system for outdoor sports venues. In particular we will look at designing a system for a high-school football field, although most of the design factors can be applied to other outdoor applications. This is not intended to be a definitive design document but it provides some general guidelines and factors to consider. Having visited numerous high-school football facilities as a parent, I have seen quite a variety of facilities with no two the same. This means that there will be unique aspects to every solution. It is assumed in the descriptions below that the seating on one side of the field is for supporters of the home team and visitors from the opposing school are seated on the other side of the field.

Most of facilities I have seen are medium-sized and can be covered as described below. For larger facilities, more amplifiers and loudspeaker may be required. It is the responsibility of the designer and installer to evaluate each application and determine the best solution. While these solutions meet the most important sound reinforcement requirements, they are not perfect. In most cases the sound level in the visitor stands is not as high as the home field stands. However,

these solutions can provide sound level sufficient for the audience to easily hear. Properly installed, the equipment recommended will provide good music playback fidelity and audience coverage. It should be able to make the customer happy without breaking the bank. As in all installations, but in particular installations outdoors, every step must be taken to ensure the safety of the users and attendees. Remember wind, snow and rain add stress to the loudspeakers mounts. Make sure every mount is securely attached and has a safety backup.

To get started, we first need to establish how the system is going to be used. Anymore, music playback has become the norm at sporting events. In the past, reentrant horns were common place for these applications. While they worked ok for voice applications, their limited bandwidth and high distortion did a rather poor job with music. Expectations have changed. A modern sound system must not only project voice well but it needs a wide bandwidth with good bass response for music.

For the examples below we will use Peavey Elements™ 115C loudspeakers. The weather resistant design and frequency response (56 Hz to 18 kHz +/-3 dB) of these loudspeakers makes them a good choice for this application. Other important specifications of these speakers are: horn dispersion (60 x40 or 105 x 60) and sensitivity (96 dB 1W 1M). These are not the only loudspeakers in the Elements loudspeaker line you could install, but using these speakers for all of the examples below, makes it easier to compare solutions.

We are going to assume that we can cover the field adequately with 4 loudspeakers, although we need to examine each case carefully. To drive these loudspeakers we are going to use an IPR™ 5000 amplifier with two speakers connected to each channel. The continuous power rating of the speakers is 500 Watts continuous with a program rating of 1000 Watts each. The amplifier is rated at 1510 Watts into a 4 Ohm load each channel providing 755 Watts to each of our 8 Ohm speakers. This looks like a good match.

Ignoring wire loss, using the IPR 5000 allows us to produce the rated sound pressure level of 123 dB at 1 Meter from the speaker. If we stack two speakers to cover the same area, the SPL increases 6 dB to 129 dB. We will use these numbers in design examples below.

Before we explore specific system design options, we will look at some of the factors that influence our choices.

Horn coverage angles.

In very general terms, the coverage angle of a high frequency horn is given as the number of degrees of an angle, both vertical and horizontal that the speaker covers before the signal level drops 6 dB in level. This only addresses the frequency range the high frequency horn reproduces. So for the Elements 115C with a crossover frequency around 1.75 kHz, the coverage angles only apply above that frequency. The coverage of the horn varies some with frequency but this provides some good guidelines to work with.

Below the crossover frequency, the coverage is more of a circular pattern that keeps getting wider as the frequency gets lower. This means the low and mid frequencies will be louder than mid highs and highs when we are outside the coverage pattern of the horn. One important take away from examining coverage angles is that we need to make sure we have sufficiently wide dispersion for the seating area we are trying to cover. Another important note; we can take advantage of the more limited vertical coverage of these speakers to reduce the sound level for people that are close to the speaker and below its optimal coverage pattern.

The 115C with the 105 x 60 horn can cover a very wide area. This is particularly important when the coverage area is close to the speaker. The sensitivity of the speaker is the same as the 115C with 60 x 40 horn so there is not a penalty for using it.

The main reason to use the 60 x 40 horn is to limit the coverage. If the speaker is mounted behind the Home seating and you want to cover the other side of the field from there, its more limited vertical coverage will help keep its sound level down on the home field side. (at least in the frequency range the horn)

Speed of sound

Sound travels relatively slowly. Think about how long it takes to hear the thunder associated with a lightning strike. It takes over 1/4 of a second for sound to travel from one goal line on the football field to the other. The speed depends on temperature and humidity but we will round it to 1125 feet per second (340 Meters/second). Although we can detect delays much shorter, we start perceiving a discrete echo if we hear sound from two sources or signal paths when one arrives more than 50 mS after the other. A difference in travel distance of 55 feet between speakers creates a 50 mS delay. A reflected path that is 55 feet or more longer that the direct path can also create an echo. At 50 mS, the echo has little disruptive effect on our listening. Only as the delay gets longer is listening adversely affected. If the first arrival is much louder than the second the problem is reduced. It is important to keep this in mind when we position speakers with overlapping coverage. The path length will be different as we move between speakers but so will their sound level.

Gain before feedback.

Acoustic feedback in a single microphone system occurs when sound from the loudspeaker re-enters the microphone louder than the sound that created it. In most cases the potential problem with feedback can be addressed through careful design, planning and operation. The construction of the press box, location of the speakers and location of windows all factor in. There should not be a direct path from the loudspeaker to the microphone, even through a window. Masonry walls isolate sound better than tin. Maximizing the distance from speaker to microphone also helps. Of course the position of the microphone is also important. The announcer that leans out the window of the press box with the microphone is asking for trouble. Having the announcer work the microphone

closely is always a help. Remember to turn down the low and low-mid frequencies on the mixer announce-mic channel. This will reduce the "proximity effect" (boominess) that close working of a directional microphone produces. The announcer should also be trained so that they have an understanding of how loud the sound needs to be at their location to get proper coverage of the entire audience.

To minimize problems with feedback:

Position the loudspeakers and microphone to keep the sound returning to the microphone as low as possible. Start with a strong signal at the microphone and keep the microphone close to the announcers mouth. Changing the mic to mouth distance from 2 inches to 1 has the same benefit as moving the loudspeakers twice as far away.

Sound attenuation with distance

Sound attenuates 6 dB every time the distance from the source is doubled.

Attenuation dB=20log(distance 1/distance 2)

Reference 1Meter

Distance	1 Meter	10 Feet	20 Feet	40 Feet	80 Feet	160 Feet	320 Feet
Attenuation	0	10 dB	16 dB	22 dB	28 dB	34 dB	40 dB

To provide as even a sound coverage as possible, take care not to position the loudspeakers any closer than necessary to the nearest listeners. This is particularly important for loudspeakers intended to cover visitor seating from the home field side. A little extra elevation of these speakers can really help as you can see from the attenuation chart. In addition to the attenuation with distance to the near seats, the attenuation due to the off-axis response of the speakers can reduce the sound level another 6 to 10 dB.

Loss of signal in the speaker wire

The wire loss charts below show the relative loss of signal in dB and the loss of power based on 1510 Watts produced per channel of a IPR™ 5000 driving two 8 Ohm speakers each channel. The 8 Ohm load chart applies to use of separate wiring to each speaker. The 4 Ohm load chart assumes that the two speakers are connected in parallel at the speakers and driven by a single cable pair.

Wire loss: Wire Gauge vs Distance for 8 Ohm Load

Feet		50	50	100	100	200	200	300	300	400	400
Gauge	Ohms/Ft	dB	Watts	dB	Watts	dB	Watts	dB	Watts	dB	Watts
8	0.001209	0.07	6	0.13	11	0.26	22	0.39	33	0.51	43
10	0.002036	0.11	10	0.22	19	0.43	37	0.64	5	0.84	70
12	0.003238	0.17	15	0.34	30	0.68	5	1.00	82	1.30	106
14	0.00515	0.28	24	0.54	46	1.05	87	1.53	123	1.99	156

Feet		500	500	600	600	700	700	800	800
Gauge	Ohms/Ft	dB	Watts	dB	Watts	dB	Watts	dB	Watts
8	0.001209	0.63	53	0.75	63	0.87	73	0.99	82
10	0.002036	1.04	86	1.23	101	1.42	115	1.61	129
12	0.003238	1.60	128	1.89	149	2.17	168	2.44	186
14	0.00515	2.42	185	2.84	212	3.23	236	3.61	258

Wire loss: Wire Gage vs Distance for 4 Ohm Load

Feet		50	50	100	100	200	200	300	300	400	400
Gauge	Ohms/Ft	dB	Watts	dB	Watts	dB	Watts	dB	Watts	dB	Watts
8	0.001209	0.13	1	0.26	2	0.51	43	0.75	63	0.99	82
10	0.002036	0.22	19	0.43	37	0.84	70	1.23	101	1.61	29
12	0.003238	0.34	30	0.68	57	1.30	106	1.89	149	2.44	186
14	0.00515	Do Not Use									

Feet		500	500	600	600	700	700	800	800
Gauge	Ohms/Ft	dB	Watts	dB	Watts	dB	Watts	dB	Watts
8	0.001209	1.22	100	1.45	117	1.67	133	1.88	148
10	0.002036	1.97	154	2.31	178	2.65	200	2.97	220
12	0.003238	2.95	19	3.44	248	3.90	275	4.34	299
14	0.00515	Do Not Use							

Note: The analysis, observations and recommendations below make a lot of generalizations and assumptions. When designing a system, you need to look at the specific details of each application determine what solution will work best. For example, what are the dimensions of the seating areas? What is the shape and construction of the press box? Where are the light poles located?
Let's look at where to locate the loudspeakers.

Here are some of the options:
- **Press box on home stand side of field**
- **Light poles on home stand side of field**
- **Light poles home stand side of field and on visitor side of field**
- **Scoreboard**

Press box on home stand side of field

Advantages:
- The amplifier and mixer can be located in the press box which keeps the speaker lines short for less signal loss in the wire.
- It will be easier to route the speaker cables.
- Depending on the configuration of the press box, it may be easier to mount the speakers.
- It may be practical to install the speakers from ladders or scaffolding instead of requiring a tall man lift.

Disadvantages:
Depending on speaker location in regard to seating.
- There will be greater difference in sound level between near and far seats. To get full volume across the field can make it louder in the near stands.
- Can be more prone to feedback in press box microphone

Details:
Equipment list:

2 Elements™ 115C speakers with 105x60 horns to cover home stands

2 Elements 115C speakers with 60x40 horns stacked to cover visitor stands these may provide some coverage of the center of home stands as well.

IPR™ 5000

PV®10BT mixer

Depending on height of press box above stands, there may be an advantage to adding a small speaker to improve high frequency coverage of home field seats in front of the press box.

Peak sound level in visitor stands:

Assume 750 Watts each speaker SPL = 124 dB at 1 Meter

Add 6 dB for using two stacked speakers 130 dB SPL at 1 Meter

Assume approximately 260 feet from speakers to middle of stands.

Attenuation 38 dB

Peak sound level in visitor stands 90 dB SPL.

12 or 14 gauge speaker cable is fine.

Light poles on home stand side of field

Advantages:

- If speakers can be further from near seats, the difference in sound level near to far is less.
- May be less prone to feedback in press box microphone

Disadvantages:

- Running speaker cable may be more difficult. May require installation of underground conduit.
- Longer speaker cable runs but these can still be tolerable.
- May be more challenging to cover home field stands depending on pole location.
- If there is a lot of overlapping coverage of seating from speakers on different poles, there may be noticeable delay difference between the speakers in some seats. (This can be minimized through careful aiming)
- Will likely require a man lift to install the speakers.

Details:

4 Elements™ 115C speakers horn patterns chosen to cover seating.

IPR™ 5000

PV®10BT mixer

There are a lot of variables here. The biggest variable is where are the light poles located and how many there are. If there is a pole located at the center line of the field, you have the best situation. Mounting all of the loudspeakers on that pole eliminates the delay problem experienced with multiple speaker locations. The cable runs are shorter and covering the stands is likely easier.

Next easiest is if the poles are located near the ends of the stands and behind. The home stands can be covered with two loudspeakers. Use 105x60 speakers angled toward the center to cover the home stands. The best coupling between the speakers for the visitor side would be if both are on the same pole. However, you may need to split them, one on each pole.

If the poles are positioned behind the stands with seating both left and right of the pole will require some creativity and close assessment of coverage angles to see if additional loudspeakers are necessary. You may be able to use two loudspeakers with 105x60 horns on each pole, overlapping to provide coverage to the visitor side. A little high school geometry can be your friend with this one.

Light poles home stand side and visitor side of field

Same as home side pole mount except:

Advantages:

- Much better sound coverage of visitor seating

Disadvantages:

- Depending on pole location, it may require additional speakers.
- Much longer conduit and cable run to far side of the field. (assuming cable is routed around the perimeter of the field.
- If the amplifier is located in the press box there will be greater signal loss.
- Installation can be made somewhat simpler if a wireless link is used to an amplifier housed on the visitor stand side of the field. However, this can present its own problems with creating a reliable RF link, providing a weatherproof housing for the amplifier and controlling the power to the amplifier.
- Higher material and installation cost

Scoreboard mounting of Loudspeakers

Advantages:

- Potentially more even sound level in stands on both sides of the field. (Depends on length of the stands)
- Mounting speakers may be simpler than pole mounting. May require custom structure though.
- Excellent gain before feedback for press box microphone.
- Virtual point source for sound origination.

Disadvantages:

- Fairly long speaker cable runs.
- Delay experienced by the announcer may be a bit disconcerting. (could be around 0.25 Seconds)
- Sound level will be lower on home side of field (In the low to mid 90s)

Options and details:

Use two stacked pairs of Elements™ 115C loudspeaker angled to cover each side of the field. Stack the speakers horizontal, and rotate the horns. Adding a third loudspeaker to each stack will increase the sound level about 3.5 dB. You might be able to get away with a single stack of 4 speakers with 105x60 horns depending on scoreboard and stand position.

Summing up

Hopefully this paper has given you some things to think about when design a sound system for outdoor venues. There is seldom a perfect solution . It is up to you to weigh the compromises that each design decision creates to arrive at the best solution for that venue. It would be nice to have the budget and resources of a large University or pro team but systems of that scale are out of my league. (pun intended) By making careful design choices and using safe and professional installation practices, the customer can get a quality sound system that will meet their needs for years to come.

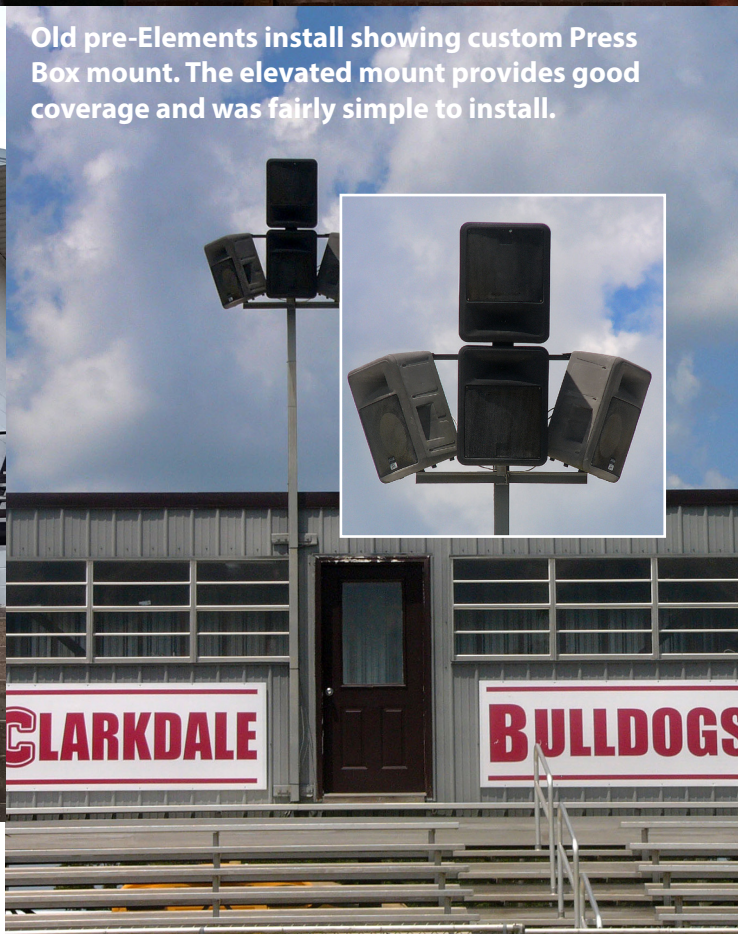

Pole Mounts

Press Box Mounts

Soccer field installation
Sxoreboard mount

Baseball Complex

Football Complex



Old pre-Elements install showing custom Press Box mount. The elevated mount provides good coverage and was fairly simple to install.

Features and specifications are subject to change without notice.

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